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THE FUTURE OF USAF AIRBORNE WARNING & CONTROL:

A CONCEPTUAL APPROACH

by

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Preface

The 1997 United States National Security Strategy advocates shaping the international environment and responding to crises—it also acknowledges that we must preparing now for an uncertain future. Joint Vision 2010, Air Force 2025, and other documents, allow us to marvel at potential roads to this uncertain future—and the tremendous leap in capabilities that the exponential growth of technology may provide. We must, however, guard against relying too heavily on concept-driven Revolutions in Military Affairs; if we accomplish simply because we can, because a state-of-the-art technology allows us to create combat and combat support systems, then our doctrine becomes a philosophical muse for scholars' debate, and our military history, a worn, leather-bound classic that gathers dust. Our tried and true lessons, such as centers of gravity, synergistic effects, and decentralized control have fundamental relevance far into the future. I have attempted to approach this conceptual study with this premise. Rather than discuss conceptual, next generation platforms merely in terms of *what we can create and incorporate into the C4I inventory*, I have examined the evolution of the USAF airborne and warning system as a *process* which includes present doctrinal tenants and past role application, as well as future concepts. I would like to thank my wife, Susan, who had steadfastly remained at my side though out my recent illness but who also supportively left my side on many weekends so I could complete this project. I would also

like to express my appreciation to my advisor, Lt Col Mike Hagen, for stepping back and allowing me to reach out and discover questions—as well as answers .

Abstract

Several conceptual approaches for next generation air surveillance and control platforms are: (1) space-based radar systems, (2) radar unmanned aerial vehicles, (3) traditional manned AWACS/JSTARS-like platforms, and (4) increased sensor capabilities on individual tactical (fighter) assets, such as internal 360 degree-coverage radars. The present focus of related literature seems to be technological advantage/cost, rather than role enhancement and system survivability as they apply to the future threat. This paper focuses on the evolving role and capabilities of the USAF airborne warning and control platform in the past, and the role and projected upgrades in capabilities of the platform in the near future (including joint and international capability comparisons). Last, it presents several next-generation conceptual platforms, and some of their core strengths and weaknesses—including potential survivability problems. Based upon this discussion, the author proposes that the combination of at least two platforms, one at the strategic and the other at the operational/tactical will best ensure redundancy, survivability, and synergy to meet air surveillance and control requirements into the next century.

Introduction

The shift from conventional war to low intensity conflict will cause many of today's weapons systems, including specifically those that are most powerful and most advanced, to be assigned to the scrap-heap. Very likely it also will put an end to large-scale military-technological research and development as we understand it today.

--Martin Van Creveld
The Transformation of War

Statement of the Problem and Methodology

This study examines several warning & control concepts to determine which best fulfills warning and control roles, and it attempts to factor in survivability in the high threat environment of tomorrow. This conceptual approach takes into account that the current system, the Airborne Warning & Control System (AWACS), is a sub-segment of a larger command and control system which includes other ground and airborne units. Last, this conceptual approach examines the evolution of the USAF airborne and warning system as a process which includes present doctrinal tenants and past role application, as well as future concepts.

Background

In today's post Cold War, unipolar world, speculation about the military's future role abounds. Scholars and soldiers attempt to analyze everything from world political economy to information technology in an attempt to predict the playing field, rules, and gear, of the future conflict game. Unfortunately, our inability to predict future warfare includes (but is not limited to) WW I, WW II, the Korea stalemate, the Iran/Iraq War, the Falklands, the series of Arab-

Israeli Wars, the miring of Vietnam, the shutout of Desert Storm, and many other contingencies involving the use of conventional air forces.

Thus, we premise our preparation for future conflicts with the following two doctrinal thoughts: First, we must be prepared to fight wars utilizing conventional airpower, and second, technology, conventionally applied, made a difference historically, in the prosecution of air war.

In relatively recent history, the USAF applied technological superiority through employment of AWACS, during conventional air operations in the Gulf War. When the next war occurs, AWACS, in its present form, may no longer be the platform of choice. The useful lifetime of the AWACS platform will depend upon at least two factors: (1) life-cycle airworthiness, and (2) technological obsolescence. The high mission tasking for USAF AWACS during the past 20 years "has made the E-3 older than the B-52 and KC-135 fleets in airframe hours." Never-the-less, 84 percent of the USAF AWACS fleet (assuming no war or peacetime losses) are projected to remain air worthy until 2035.[1] The question of whether the current AWACS platform will be technologically obsolete by 2035 is another matter. Given the lead time required to field new (major) aerospace systems, the USAF should urgently analyze requirements for next-generation, follow-on warning & control system(s), whether ground-based, airborne, or space-based; and whether manned or unmanned.

Limitations

The author acknowledges certain limitations to the study. First, and foremost, while we can speculate about technological change, no one can accurately and forthrightly claim to definitively nor exhaustively forecast what technological advances (or corresponding RMA) will exist twenty years from now. For example, present discussions concerning the migration of airborne early

warning (AEW) radars to space satellite platforms during the 21st Century, presupposes that radar will be the airborne (or spaceborne) sensor of the future. Second, since we cannot definitively forecast technological changes, it logically follows that we can cannot accurately forecast how technology will influence our future aerospace doctrine. For example, warfighting strategy during WW I would have radically changed had the technological innovation of caterpillar tread as applied to the armored tank been foreseen.

Scope

Last, this paper assumes there is a logical and progressive relationship between AWACS capabilities, the AWACS role, and ultimately AWACS relationship to USAF doctrine (though in reality the process could probably be modeled as cyclical). When this logical progression is examined in light of the past/present, "tomorrow," and the future, this author believes that the discussion should focus on the *known* or *envisioned* rather than moving a further unexacting step to predict the *unknown* beyond it. Table 1 illustrates this best:

Table 1. Relating AWACS Evolution to the Past, Present, and Future

	AWACS Capability (applied technology)	***→ AWACS Role / Employment***	***→ Relation to Doctrine***
Past/Present	Known	known	interpreted
Tomorrow *(10 -15 years)*	Known based on existing technology with logical applications	**envisioned** assumptions: threat, relationship to other USAF systems, nature of conflict etc.	**unknown** inability to forecast doctrine's future evolution
The Future *(16+ years)*	**Envisioned** assumptions: technologies will exist, be predominate, and be affordable	**unknown** inability to forecast threat, relationship to other platforms, nature of conflict etc.	**unknown** inability to forecast doctrine's Future evolution

Chapter 1

The Past and Present: The Evolution of AWACS

> *"Situational Awareness" is a term much in vogue, but fighter pilots have seen it for decades as the vital difference between winning and losing in combat. It determines combat outcomes more than all other factors involved, including previous combat experience.*
>
> --Benjamin S. Lambert

Air Defense Command and Tactical Air Command specified the need for an Airborne Warning and Control System in 1966. The E-3 AWACS reached Initial Operating Capability (IOC) some 11 years later, and the last of 34 E-3 aircraft was handed over to the USAF after a further seven years, in 1984.[2]

The AWACS Role

The E-3 AWACS role in conflict has evolved since its reached Initial Operating Capability (IOC). Three aspects of the evolution bear mention.

First, there has been a trend in the evolution of the scope of the AWACS role. During the *late 1970's* and *early 1980's*, the E-3 supported strategic defense against Soviet bombers. As such, the USAF saw it as highly-flexible, speedily-deployed asset which would provide airborne early warning against the *strategic threat*. Later, during the *1980's*, while the E-3's role remained attentive to the Soviet bomber threat, it also began to greatly focus on control of tactical assets in the *tactical environment*. By the beginning of the *1990's* during the Gulf War, AWACS provided

control and battle management support to offensive counter air forces *theater-wide (i.e. operational level)*. During that war, US and Saudi E-3s data-linked with other airborne E-3s (and other combat support aircraft, such as ABCCC, Rivet Joint, and the USN E-2 Hawkeye) to provide a *comprehensive, theater-wide* three-dimensional surveillance picture. This theater-wide surveillance picture was continuously data-linked to ground-based theater command and control centers[3] and was integrated with data from ground-based radars.

Second, there has been a trend in the evolution of the <u>weapons control</u> role. AWACS initially provided an early warning capability for the Soviet Bomber Threat. At this time AWACS had a limited control capability but could be allocated responsibility by a ground-based command and control center for directing a *limited number of closely controlled defensive intercepts* with the "interceptor" aircraft requiring large amounts of assistance from the AWACS controller. At this time, AWACS was an augmenting control platform for ground-based control units.

With the demise of fighter assets such as the F-4C and F-106, and their replacement by the more capable F-15 and multi-role F-16, less intercept control assistance was required in the later half of the 1980s, and AWACS assumed a *broader role as a "tactical advisor" for greater numbers of fighter aircraft* operating in a tactical area limited by the AWACS' radar coverage. During this decade, AWACS' "advisory assistance" to both offensive and defensive fighter assets in the tactical environment became more prevalent at Red Flag and other major exercises. At this stage, the AWACS control function moved toward autonomy (i.e., no longer merely an augmenting platform for ground-based control units).

During the 1990's, AWACS control matured into theater-wide *battle management*. By networking the tactical air pictures of several or more AWACS through data link, AWACS

provided theater-wide offensive assistance to large numbers of strike packages (and could have done so for defensive air forces, if the situation had required), and AWACS also *assisted with the majority of air battle tasks*, to include theater-wide safe passage, air refueling, close air support, SAR, threat warning to non-fighter aircraft, etc. Full autonomy of the control responsibility became a reality.

Third, technological upgrades to the E-3 helped enhance the revolution in roles. Of the 24 initial E-3As, 22 were later upgraded to E-3Bs. Enhancements included greater computer capabilities, secure communications capability, maritime surveillance capabilities added to the radar suite, extra radios, and five additional radar display consoles. The extra consoles allowed the E-3 to carry more controllers thus allowing a broader range/greater amount of control activity. The subsequently delivered, last 10 USAF E-3As built were upgraded to E-3Cs, with additional command and control capabilities.[4]

AWACS Employment

The USAF employs 33 E-3s today (one of the originally 34 crashed in Alaska). About five E-3's remain in depot maintenance at any given time, and one is a permanent test bed for upgrades and modifications. This leaves approximately 27 available E-3s for world-wide operations and training missions at any given time. These mainly operationally support USCENTCOM, USSOUTHCOM, USEUCOM, USACOM, and NORAD.[5]

According to MCM 3-1, Volume XV, AWACS has the ability to perform three related missions: Surveillance, Weapons Control, and Battle Management.[6] In a much broader sense, however, AWACS is a versatile asset which the military Instrument of Power (IOP) can deploy to show American resolve, critically support air operations during war, or operate anywhere

along the spectrum between these two extremes. Figure 1 (below) summarizes historical AWACS employment versatility.

A number of US allies employ their own versions of the AWACS. Both NATO and the Kingdom of Saudi Arabia purchased AWACS from the United States in the 1980's. During the 1990's, Britain, France, and Japan purchased AWACS tailored to their own specifications. Today, interoperability (i.e., ability to share data and communications) between our AWACS and allies is critical for combined operations.

AWACS and the Tenants of Airpower

How, if at all, does the current AWACS platform support the USAF's doctrinally-related Tenants of Airpower?

Centralized control and decentralized execution. AWACS enhances centralized control; by significantly contributing to a comprehensive, real-time air surveillance (and possibly surface surveillance) picture. AWACS platforms, when linked to the Air Operations Center (AOC) or equivalent, provides the air commander a "big screen, play-by-play" display which helps him, as AFDD-1 stipulates, "focus the tremendous impact of air…power wherever needed across the theater of operations."[7] What about centralized control of the AWACS asset? AWACS sorties, like other theater air assets are tasked in the ATO; they may be apportioned, but usually this is should not be required unless the area of operations exceeds the radar coverage which the available AWACS provide.

Crisis Warning/Visible Surveillance	AWACS/JSTARS Integration
Poland	Bosnia
Iran/Iraq War	Foal Eagle
Korea	Nellis AFB
Air Traffic Control of Assault Forces	**Enforce International Sanctions**
Panama	Saudi Arabia
Haiti	Turkey
	Bosnia
Halt Phase of Crisis	**"Link War"- Link 16 Operations**
Saudi Arabia	ASCIET
Sudan	Blue Flag
Egypt	
Maritime Operations Support	**Weapons Control**
Caribbean	Desert Storm
Atlantic	Bosnia
Pacific	
SAR/Time Critical Targets	**Isolate Battlefield**
Desert Shield/Desert Storm	Grenada
	Haiti
Counterdrug Operations	**North American Air Sovereignty**
Columbi	Alaska
Peru	NORAD
Carribbean	

Source: Executive Summary, AWACS' Mission & Challenges Briefing (Lt Col Bart Dannels, Chief, Surveillance Requirements, HQ ACC, December 1997), 2.

Figure 1. Historical USAF AWACS Employment

Flexible and versatile. AWACS is a flexible asset. The platform can ground-abort, if required, or stay on station longer or shorter than originally planned; it can maintain an area of operations or quickly fly to another area in the theater; it can control more or less missions than originally planned, and it can take on unforeseen control missions; it can perform self-protection by retrograding in the face of an air threat; it can provide air surveillance, control, battle management, or any combination of the three—and not necessarily under pre-planned circumstances. It's crews are trained to react to the ever-evolving air battle—to what they hear, real-time, on their headsets and what they see , real-time, on their console screens. AWACS is also versatile, as demonstrated in Figure 1, above.

Produces synergistic effects. By reacting to the real-time air battle, and by providing advisory control and battle management across a wide range of missions including air-to-air, air-to-ground, and combat support missions, AWACS can shift their focus to where their assistance

is most needed. While doing this, the combination of their macro, "big picture," assistance and the micro prosecution by individual elements of the air battle produces synergistic effects.

Uniquely suited to persistent operations. AFDD-1 states that "unlike surface power, air…power's inherent exceptional speed and range allows its forces to visit and revisit wide ranges of targets nearly at will."[7] Precisely because AWACS can be positioned to provide an optimal air picture, its speed and range allows placement to support air operations which visit and revisit a wide range of targets. It is only limited from advancing on the three-dimensional battlespace by self-protection considerations (i.e., SAM and enemy fighter proximity).

Operations must achieve concentration of purpose. "With forces as flexible and versatile as air… power, the demand for them will often exceed the available forces," thus leading to a risk of "failing to achieve operational-level objectives."[8] As already mentioned, AWACS does not need to be apportioned, ordinarily, for certain types of missions (they can support a wide variety of air-to-air or air-to-ground missions, simultaneously). Therefore, their demand should not exceed the available forces *in a given operational theater*, unless heavy attrition takes place. None-the-less, AWACS is a "high demand, low density" asset, and as such, shortfalls in availability may occur *between different theaters of operations*, or during geographically-widespread contingencies.

Operations must be prioritized. "The air commander should assess the possible uses of air…forces and their strengths and capabilities to support (1) the overall joint campaign, (2) air operations, and (3) the battle at hand."[9] The convenience of AWACS is precisely that it supports <u>other</u> forces which must be apportioned. Once apportionment takes place, AWACS can support a wide variety of different missions supporting the land, sea, and air areas of operations.

Operations must be balanced. "An air commander should balance combat opportunity,

necessity, effectiveness, efficiency, and the impact of accomplishing assigned objectives against the associated risk…”[10] AWACS obviates some of the burden on the air commander for each of these tasks: AWACS advisory control during real-time air operations, increases *combat opportunity*, due to the controller’s large radar coverage area; additionally, effective advisory control which includes accurate and timely air and ground threat locations increases fighter pilots’ ability to react with *effectiveness* and *efficiency*—and as *necessity* dictates. Information about the enemy’s location, strength, and actions, displayed on the controller’s console screen, allows the controller to advise offensive air assets of *risks* to their *accomplishment of objectives*.

Chapter 2

Tomorrow: A Transition to the Future?

> *It is a world where a "peer competitor"—that is, another superpower—is not expected to emerge until after 2015. However, it was judged likely that well before then, "more than one aspiring regional power will have both the desire and the means to challenge US interests militarily."*
>
> - John A. Tirpak
> Projections from the QDR

Role vs. Capability

The USAF has several major AWACS upgrade programs in progress. With a few exceptions, each of these programs represents an enhancement to an existing applied technology (radar, data link, comm systems etc.). As such, it is tempting to think of these upgrades as extending the present AWACS platform, rather than providing a transition to future platforms. One must ask, however, which first deserves consideration, the transition of the *platform*—or the transition of the *role* for which the platform is used.

As noted earlier, however, the role of AWACS has evolved since IOC from *strategic* defense, to *tactical* offense/defense, and then to *operational* offense. A further role change is on the immediate horizon. With present commercial communication satellite constellations, information sharing via the Internet is creating a global civilian information sharing system. The implications for shared airborne-radar surveillance boggle the mind. With military

communications satellite technology, the theater air picture can be linked world-wide; to joint command headquarters, to regional command elements, to adjacent or associated theaters, and other geographically-separated military agencies, if required. The next step in the role of AWACS, currently in progress, involves the addition of a *strategic* role. This new role, however, will not be a return to a basic strategic bomber defense; instead, it will focus on *strategic C4I and battle management, while retaining elements of operational offense*.

In-progress AWACS Capability Upgrades

Present AWACS modernization programs do not provide a transition to the future. Some of the upgrades are stop gap measures to keep the platform technologically viable (for example, improved radar sensitivity will allow detection of the projected cruise missile threat) or technologically enhance the platform for better performance (for example, more user friendly screen displays for controllers). Other upgrades are designed to assist the transition to the new role mentioned above.

The USAF AWACS fleet currently undergoes three modernization programs: (1) Block 30/35, (2) Radar System Improvement Program (RSIP), and (3) Computer Display modernization (C&D). These upgrades provide the following:[11]

- Increased radar picture sensitivity, and accuracy
- Passive detection (ESM) sensor capability
- AWACS participation in the Global Command & Control System
- Accurate, data-linked air picture to future stealth fighters (F-22, Joint Strike Fighter) which, in turn, will allow these fighters to leave their own radars off (i.e., limit detectable emissions) until just prior to launching radar-guided missiles

Table 2 (below) summarizes each of these upgrade programs in terms of program implementation, notable upgrade elements, and significant capability increases.

Table 2. Current AWACS Capability Upgrade Programs

UPGRADE PROGRAM	IMPLEMENTATION	ELEMENTS	CAPABILITY
Block 30/35	2001 Full Ops Capability	JTIDS terminal GPS ESM Processor replacement	Full interoperability More accurate target tracking passive emitter detection and ID increased processing power
RSIP	2004 Full Ops Capability	Radar sensitivity Radar ECCM Radar Processing	detect/track stealthier targets less jammable radar better reliability
C&D	Step 1 / 2003 Full Ops Capability Step 2 / 2005 Initial Ops Capability	User interface Console display and software Improved Computing architecture	less time operating system—more time conducting mission greater operator situational awareness

Source: Executive Summary, AWACS' Mission & Challenges Briefing (Lt Col Bart Dannels, Chief, Surveillance Requirements, HQ ACC, December 1997), 5.

One aspect of the C&D upgrade portends the possible migration of the battle management function to a physical location other than that of the (radar/ESM) sensors; the Step 2 upgrade will "allow the operator to control AWACS sensors from a ground TACS [Tactical Air Control System] element or another AWACS…"[12]

A Joint Contrast: The USN's Airborne Warning & Control Upgrades

No discussion of airborne warning and control upgrades would be complete without contrasting current USN and USAF upgrades. USN E-2s and USAF E-3s have shared a common air picture through data-link, during fleet exercises and also during Desert Storm. The US must therefore ensure that the two AEW platforms maintain interoperability, and preferably synergize each other's performance, into the foreseeable future. Should AWACS transition to a new platform(s), the USAF will need to ensure that the platform(s) remain interoperable with the

USN AEW system—which, as discussed below, will remain the E-2 Hawkeye for some time to come.

Before comparing upgrades, one must first compare the present platforms. First, while the USAF E-3 is an airfield-based large AEW platform with a crew of up to 23, not including potential battle staff crew, the USN E-2 is a substantially smaller, carrier-based platform limited to a crew of five. Because of the size consideration, the radar dome of the E-2 lacks both the size and range capability of the USAF E-3.

Second, the E-2, as *subsegment of a larger C4I system*, conceptually differs from the E-3. Basically, the E-2, in its primary role as carrier battle group asset, acts as one of many assets (fighters, anti-sub aircraft, EW aircraft, Aegis Cruiser, etc.) with sensor capability which data-link together to create a comprehensive and eclectic surface, sub-surface, and air picture. The E-3 on the other hand, is one of a few assets which contributes to what is foremost an air picture.

While the carrier battle group shares (two-way) link information between all sensor assets, the E-3 shares two-way information via link with only a few potential sensors (EW aircraft, ground radar, and JSTARS for the ground picture). The E-3 neither links information into the fighter cockpit (unlike the E-2), nor do USAF fighters share information from their radar sensor via link with other air operations participants to extend the comprehensive radar picture (unlike USN fighters).

With that baseline, let's compare upgrades. As of May 1997, the Navy had 86 E-2C Hawkeyes—their counterpart to the USAF's 33 E-3 B/Cs. The E-2C fleet is undergoing two upgrade programs, the *E-2C Group II* upgrade, and the *Radar Modernization Group*. The E-2C Group II upgrade includes the following features:[13]

- 40% improvement in radar range

- Improved overland detection capability
- JTIDS*
- GPS*
- Voice satellite communications
- Colored (and thus more user friendly) console displays

[Author Note: asterisked items will assist continued interoperability]

The *E-2 Radar Modernization Program* is creating "an advanced demonstration radar for the Hawkeye that will bring over-the-horizon precision, overland detection, and tracking to the battle group."[14] (This author interprets "Over-the-horizon" as merely a function of the platforms altitude.) The E-3 already possesses the above capabilities.

By 2010, the Navy plans to have 75 "Hawkeye 2000"-configured E-2Cs. Half of the Hawkeye 2000 fleet *will be new builds* and the other half upgrades.[15] The Hawkeye 2000 enhancement includes a mission computer upgrade which improves target detection and tracking, thus giving it some capabilities on par with the E-3.[16] The USAF, by contrast, has no plans for further E-3 aircraft purchases.

The carrier battle groups combined subsurface/surface/air picture is used to determine and target the enemy in all three mediums. The primary consideration is defensive, i.e., battle group protection. Since battle group protection is a synergistic effort (e.g., surface forces aren't limited to their own medium, they may also be designed to attack air targets or submarines), ship-based surface-to-air missile launch systems use the extended air picture from the E-2 to locate and target enemy aircraft. Notably, the Hawkeye 2000 enhancement includes a new capability called the Cooperative Engagement Capability (CEC):

> CEC-equipped Hawkeyes—the E-2C is the first aircraft in the US aviation arsenal to incorporate this system—will significantly extend the engagement capabilities of surface forces. The CEC-equipped Hawkeye is the key to early cueing of the Aegis Weapon System, dramatically extending the lethal range of the Standard

> Missile (SM-2) against airborne low-altitude/low-radar cross section targets. This… will fully integrate the Hawkeye into the Theater Ballistic Missile and Cruise Missile Defense (TBMD/CMSD) Role.[17]

The USAF E-3 currently has no such planned upgrade (though demonstration testing has occurred). Such an enhancement would allow the E-3 to potentially cue land-based air-to-surface missile units, such as the Patriot or follow-on, future systems for enhanced TBMD.

Last, Navy officials estimate the life expectancy of the E-2C to be beyond 2015.[18] By contrast, the USAF sees the E-3 remaining viable until retirement between 2025 and 2035, provided the proper sustainment funding occurs.[19]

Other Nations, Shared Technologies and Potential Capabilities (Threats?)

In the past, nations wishing to obtain a capable AEW radar capability had to turn to either Russia or the United States. In the past many nations could not afford the price tag for purchasing one or more US E-2 or E-3 aircraft, but had no alternative platform. Now, however, "the advent of new radar technologies, smarter electronics, and lighter materials has sharply cut the cost of AEW aircraft—as well as increased the number of system providers."[20]

The USAF AWACS utilizes older radar technology. Its rotational radar antenna delays one rotation between transmitting radar waves; as a result, each target's position is updated approximately every ten seconds. Non-rotational phased-array radar systems, by contrast, use hundreds of stationary sensor elements to act as a transmitters/receivers; this system provides a continuous, real-time target position.

In the past, phased-array systems proved enormously expensive (such as those used on Aegis Cruisers and JSTARS). This is no longer the case. For example, Sweden's Saab manufactures a long/thin rectangular phased-array radar, called Erieye, which can be mounted on the top of a

small commuter-sized aircraft. Erieye detects targets at ranges up to 350 km (approximately 218 miles). [21] As a second example, Bedek, a subsidiary of Israeli Aircraft Industries, built a system for export to Chile which has four phased-array conformal antennas located on the fuselage of a Boeing 707 fore and aft of the wing. Called the Phalcon System, it detects targets to a range of 375-400 km.[22] While neither of these systems has other demonstrated capabilities of the US AWACS such as ESM—nor can they match the E-3's radar range—they are evidence of low cost alternatives available on the market which use state-of-the-art radar surveillance technology.

As US AEW technology becomes more widespread, US forces may in the future have to counter more symmetric airborne warning and control capabilities. In 1996, six to eight airborne early warning systems were sold to the PRC by Britain, who interpreted the 1989 European Union arms embargo (following Tiananmen Square) as only applying to explosives or explosive delivery systems.[23] Israel, another US ally, has no qualms about also sharing AEW technology with China. Israel has shown an interest in providing advanced AEW radar systems to China (as well as fighter and air-to-air missile technology), with the understanding that China, quid pro quo, will not sell weapons to Israel's Middle East adversaries.[24]

Regardless of potential adversaries' AEW capabilities, the USAF can counter these capabilities whether the enemy's AEW platform is airborne or on the ground in a hardened shelter, at least for the foreseeable future. *Stealth* will enable the US to strike at the time and place of their choosing.

What about potential ability to strike at USAF AWACS by using radar evading stealth fighters? Currently, only the Russians claim to have a stealth-like fighter, the MIG-1.42 / MIG 1.44 (also termed MFI, the Russian abbreviation for Multi-Functional Fighter), which is in the prototype stage. Official unveiling of the MFI took place in January 1999.[25] This fifth-generation

Russia fighter's "canard, wing, and fuselage structures incorporate carbon fiber and polymeric composite materials," and it boasts radar-absorbent materials, low radar signature, low heat signature, and fuselage compartmentalization of missiles.[26] The aircraft's approximate cost of about $70 million each is probably not economically feasible at this time, but the PRC has proposed funding to allow mutual cooperation on the project, with follow-on deliveries of the MFI to them.[27]

To return to the original question, is the present USAF AWACS a transition to future systems? The role of the AWACS platform is in transition; to *strategic C4I and battle management, while retaining elements of operational offense*. The platform, however, has no confirmed next-generation platform program under development, and current upgrades appear to be *enhancement* programs—and expensive ones at that.

Chapter 3

The Future: The Sky's the Limit, or Is It?

> *The technology needed to transfer AWACS and Joint-STARS aircraft broad area surveillance tasks to space, along with various laser and optical applications, head the list of technologies to be accelerated under the Air Force shift. For example, a distributed system of 16 small, inflatable space radar spacecraft could be flown as early as 2005 as a demonstration spawned by the new technology initiative.*
>
> - Craig Covault
> Aviation Week & Space Technology

Three conceptual evolutionary paths exist for future USAF airborne warning and control. *First*, airborne warning and control can continue to function as a manned aerial platform, though the role of this platform in the larger C2 system may change. *Second*, airborne warning and control may be delegated to a completely new platform (i.e., ground sensor units, Unmanned Aerial Vehicle (UAV), or space sensor). If, for example, satellite communications connected a ground C2 facility into a theater data-link network which included airborne fighter assets, then each fighter could perform the sensor functions of a "mini-AEW" system. *Third*, airborne warning and control functions may become split between a variety of assets, whether airborne, space-borne, or on the ground—and whether manned or unmanned.

Concept 1: Traditional AWACS Platform

This concept entails a manned, airborne warning and control system which includes all the capabilities of the E-3 today—and more. For example, use of off-the-shelf technologies would lessen the price tag for internal processing and display systems. User-friendly interfaces and software (based upon civilian computer applications), would lessen the workload per operator, and would allow either additional taskings or smaller crews.

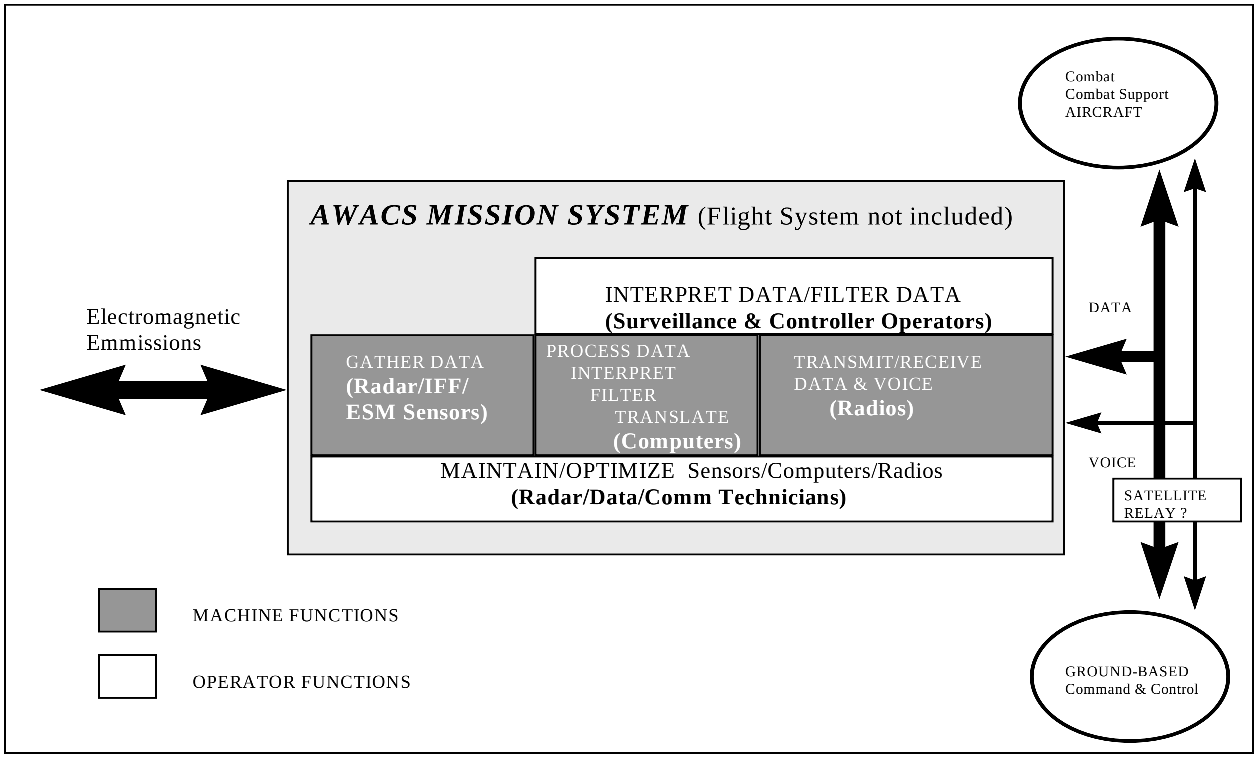

Figure 2. Present (Traditional) AWACS Mission Concept

Advanced conformal phased-array radar, instead of a radome, would lessen aircraft drag and provide continuous (as opposed to delayed rotational sweep), real-time enemy and friendly aircraft locations. Those friendly aircraft with stealth characteristics could transmit their location data directionally to a satellite which would then relay this information to the AWACS; allowing integration of friendly stealth aircraft locations into the overall air picture display. More

sophisticated ESM capabilities, may allow a "passive" air picture without radar emissions, perhaps by using triangulation and information-sharing between two or more AWACS. Active radar emissions, of course, (1) disclose an AWACS position, and (2) help focus the enemy's radar jamming efforts .

Additionally, the AWACS advanced phased-array radar system could track both ground targets and airborne targets; giving it both JSTARS and AEW capabilities. The technology to do so is already applied and manufactured on a smaller scale, in the form of the Multi-Sensor Surveillance Aircraft (MSSA), which takes modern fighter radar technology and applies it to a surveillance platform.[28] Stealth aircraft, along with other fighter, bomber, CAS, tanker, special ops, etc. aircraft would receive the air and ground pictures via data link with appropriate filters to limit the amount of information streaming onto their cockpit display. Locations of SAMS, enemy fighters, enemy vehicle movements, etc. would be at each pilot's or weapons system operator's fingertips.

Regardless of whether these innovations were incorporated, the same basic *strengths* and *limitations* of the present AEW platform would apply to this futuristic AWACS/JSTARS. For example, the present AWACS has strengths that allow it to outperform ground radar elements of the Tactical Air Control System, such as Forward Air Control Posts, and Control and Reporting Posts.

One such strength, as mentioned earlier, is that it is both flexible and versatile. AWACS potentially project combat support and surveillance functions into theater within 24 hours or less. In conjunction with other AWACS, it then can provide theater-wide coverage, or be singularly used to support small non-combat contingencies, such as embargo operations. Thus, it proves a

versatile asset for either the strategic, operational, and tactical levels of warfare—or, with global satellite communications, for all three simultaneously.

A second strength, evident during combat operations, entails ability to retrograde. Since the platform provides synergistic effects to offensive combat operations, and provides real-time information which allows command centers to "visualize" the air battle, enemy forces may perceive it as a decisive point worth attacking. The AWACS extended-surveillance capability allows it to detect incoming threats at great distances and retreat in the face of direct enemy air threats. When the threat resides, AWACS can once again return to station to continue synergizing both C2 and offensive operations.

A third strength of AWACS is its ability for autonomous or semi-autonomous operations. Since the AWACS encapsulates both surveillance and control capabilities, each individual aircraft can manage a tactical or limited campaign air battle even if its link capabilities are inoperative. The AWACS crew can be tailored to include battle staff or even commanders to enhance autonomous abilities. AWACS crews train to share the most important air picture elements via voice radio with other units in theater; therefore, AWACS aircraft, even without link ability, can perform semi-autonomous operations in conjunction with other airborne AWACS across an entire theater of operations.

While maintainability would usually be taken for granted as an general aircraft inevitability, this characteristic is a strength of the AWACS concept (assuming maintenance is not problematic due to over-aging, extension of the original life cycle, etc.). First, the platform carries its own radar, communications, and computer technicians. In the event of technical difficulties to equipment contained within the fuselage of the aircraft, these technicians (barring the need for unavailable spare parts) can correct the problem, thus allowing the AWACS, still on orbit, to

continue the mission. Second, should the aircraft need major maintenance to mission systems, it can be flown out of theater for repair and then returned as speedily as is relatively possible.

While AWACS brings definite strengths to the fight, it also brings weaknesses. First and foremost, while some AWACS communications systems are true over-the-horizon or satellite-capable, the AWACS radar, IFF, and ESM sensors are all line-of-sight. When first envisioned as the "airborne early warning" radar platform detecting the Soviet bomber threat, AWACS, at a vertical altitude of approximately six miles, owned the C2 high ground—at least the highest ground available before the growth of space assets. While operating at medium altitudes greatly increases aircraft detection ability, terrain limits line-of-sight sensors' range, especially in high mountainous terrain. A second, related limiting factor is the enemy air defense threat—AWACS must operate away from SAM envelopes and enemy fighter patrols. Therefore, line-of-site limitations combined with orbit-location limitations decreases the ability of AWACS to provide an optimal air surveillance picture. During Desert Shield/Desert Storm, orbit location (until air supremacy was achieved) limited US and Saudi AWACS radar picture into Iraq. However, the flat terrain of Southern Iraq proved ideal for observing enemy/friendly air movements. During the next war, the USAF may not be as fortunate.

A second weakness pertains to staging location. Depending on the theater, airbasing requirements may be required from a host nation. Since AWACS may deploy in the pre-hostility phase to surveille potentially threatening air activity across a border, it may require basing, comprehensive ground security, and even fighter escort. If theater basing is not available or convenient, overflight permission may be required from neighboring countries. To illustrate the point, many of the NATO AWACS missions flown during early Bosnia operations took off from Central Germany, flew to the AOR, and returned at flights' end to central Germany. While host

basing was not a requirement, in this case, overflight permission from Austria and former eastern block countries was a prerequisite.

A third weakness of AWACS is cost. Initially, each E-3A (in the 1970's) priced in at well over $100 million, with substantial costs being added on for each upgrade. The E-3's sustainment costs, today, averages $5,000 a flight hour—two-fifths of which is consumables (fuel, etc.), and the other three-fifths, depot repair costs.[29] After determining that most weapons systems costs occur *after* deployment, the DoD now places great emphasis on "back-end" sustainment costs receiving "up-front" design attention.[31] Upgrade programs prove high, also; NATO's AWACS System Improvement Program cost NATO approximately $700 million with a fleet of only 18 aircraft. A last thought: The cost for France to purchase a four E-3 package totaled $704 million.[33] The cost of future upgrades, not to mention new AWACS acquisitions, maybe beyond the USAF's future budget.

Concept 2: Airborne Warning and Control Delegated To a New Platform

Each of the following options, ground sensor unit, drone, or space-based sensor, should be discussed individually:

The **first platform**, a new *ground based sensor* can be ruled out, immediately. The weaknesses of existing ground-based warning and control radar systems, whether fixed or mobile, pertains first and foremost to line of sight limitations. Our current mobile ground radar system, Modular Control Element (MCE) can contribute air surveillance, airspace control, etc. on the friendly side of the FEBA; it can provide high level extended radar range across the FEBA into enemy territory, and possibly even extended medium range coverage depending on terrain. But, in the absence of ideal conditions (placement on the top of a plateau surveilling flat land, for

example), ground mobile radars do not provide extended low level coverage due to curvature of the earth. Ground-based mobile radars remain much more suited to defensive operations and control of friendly airspace, when compared to the flexibility, versatility and offensive role of AWACS.

The **second conceptual platform**, an *AEW UAV*, can extend airborne surveillance beyond the range of current manned AWACS—perhaps for greater operating periods. According to a thesis completed at The School of Advanced Airpower Studies, Maxwell AFB, UAVs... "are expendable or recoverable, and can fly autonomously or be piloted remotely."[32] The study, while discussing current and emerging unmanned vehicles, classifies two primary types, *Tactical* (10 hours or less flight time and operating radius of not more than 150 miles), and *Endurance* (greater than 10 hours / radius greater than 150 miles).[33] Due to radar surveillance requirements extending far into enemy territory, the AEW unmanned aerial vehicle would need to be the *endurance* type. The UAVs would also most likely be remotely piloted and would require recovery. An AEW sensor, unlike an RF-4 flying a planned reconnaissance route; is a *continuous* sensor with a flexible, dynamic surveillance area. Since continuos communications are required for the UAV to transmit radar surveillance data to the user anyway, continuous communications could remotely pilot the UAV's surveillance flight to unexpected gaps in sensor coverage (due to loss or malfunction, for example).

UAVs, since they do not carry personnel—mission specialists as well as pilots—would be used as pure sensor platforms or instead, could carry radar data-processing hardware/software in addition to the sensor (but at a greater cost per unit, greater fuel constraint, and higher value loss if lost).

In order to sustain a comprehensive air picture, many AEW UAVs spread around the theater would surveille collectively. Therefore GPS, or some other form of reference system equipment to help in multi-source radar data correlation, would have to be carried by each UAV. The implication is that the AEW UAV would need to data link with command and air battle management personnel (which would display and assist commanders in exploiting the air picture), and also link to controllers who would be responsible for filtering the air picture and highlighting threats to fighters, via radio or data link.

There are two "sub-concepts" for AEW UAVs: *Sub-concept 1:* Many "pure radar" UAVs could extend the coverage of on-orbit AWACS to high-interest areas beyond AWACS radar coverage. Each UAV would transmit raw data via link to the AWACS and the AWACS would process the data and incorporate it into the air picture. *Sub-concept 2*: Many pure radar AEW UAVs operating across the theater of operations would singularly provide a comprehensive radar picture. This "hive" principle, i.e., dispersing the "gather data" (see Figure 2 for comparison to traditional AEW system) function of the traditional AWACS among many smaller sensors, requires data link to a theater (or even regional or global) C2/battle management center, either via airborne radio relay (in theater), or via satellite communications. In addition, two-way voice and possibly data relay via satellite must be available between the C2/battle management center, whether in or out of theater, and airborne assets, in theater, such as fighters.

Several strengths and weakness exist for the AEW UAV concept. The first strength involves cost. UAVs with only the "gather data" and "transmit data" elements (see Figure 2) would be relatively more inexpensive than the AWACS system—even though many would be needed since each would be relatively smaller/lighter and would probably lack the power needed to extend radar range as far as the traditional platform. Second, either Sub-concept 1 or 2 could

provide extended coverage by extending the AEW platforms' orbit areas across the FEBA without placing an extremely expensive platform with a large crew in jeopardy. Third, with Sub-concept 2 (the hive principle), the sensor element of the high value asset becomes dispersed, which makes knocking out the "data gathering" function harder to achieve.

On the other hand, there are weaknesses. The more capabilities added to the AEW UAV, the larger and more costly the platform becomes (Examples of additional capabilities are: ESM, remotely-controlled maintenance/optimization of mission systems, remote piloting capability, and extended range/endurance/altitude). Second, radar remains a line of sight sensor—meaning the AEW UAV must fly at medium altitudes and become detectable to the enemy air defense system. To those who would advocate overcoming the altitude detection problem by incorporating stealth characteristics, remember that the UAV is an emitter, and an easily detectable one at that. Should the enemy possess a radar-seeking/homing missile, either surface-to-air or air-to-air, the AEW UAV might present an easy target. Last, a smaller, less powerful emitter might not possess the capability for "burn through" during ECM from powerful enemy jamming sources.

As a final note, remember that the traditional AWACS platform had autonomous and semi-autonomous capability. Sub-concept 2 has no such capability; since its AEW UAV (as a "data gatherer") is isolated from the rest of the system (i.e., processing, interpreting, filtering data), including the forward users (combat support and combat aircraft). Thus, the link between the sensor and the ground-based command & control center, whether airborne relay or satellite relay, becomes a decisive point for blinding the overall system.

Fighter assets could become the **third conceptual platform**. Conformal 360-degree radars (without the power or range of an AWACS) could be implemented to afford each fighter a

complete tactical surveillance bubble. Then, much the same way that the USN uses all sensor assets to add to the total surveillance picture, each fighter could link their "piece of the pie" to either an airborne platform or ground-based C2 center which would, in turn, produce and link a consolidated air picture.

Strengths include dispersal of the radar surveillance asset (hive principle), extended surveillance coverage well beyond the FEBA, and utilization of an already-existing emitter. There are, however, four weaknesses to the platform—of which at least two are critical. First, use of this platform assumes that air surveillance is only required in the area of fighter operations, and that fighter operations won't be limited to a small sub area of the theater. Second, the concept does not take into account that multi-role fighter assets switch between air-to-air and air-to-ground radar modes to optimize their immediate surveillance and targeting needs, rather than air picture surveillance needs. Third and critical, the concept assumes that utilizing a 360-degree radar sensor instead of a conventional 120-degree radar sensor does not place the fighter in any greater risk of detection; simply not true because the greater emission footprint allows greater probability of detection and thus greater enemy targeting capability. Last, and also critical, the move toward stealth characteristics by the F-22 and the Joint Strike Fighter dictates that fighter emissions be kept minimal. Optimally, these fighter platforms must either utilize passive sensors or/and receive a linked air/ground picture until going into the targeting mode.

The **fourth and final conceptual platform** raises the surveillance platform into low earth orbit. From this "gods-eye" vantage point, relatively safe above the threat of enemy tactical weaponry, satellite constellations would have true look-down capability to view enemy air and ground movements. The USAF appears to be moving in this futuristic direction: "After 50 years being almost totally focused on aircraft, major USAF development strategies are now shifting to

space in line with… the service's recent Global Engagement vision document."[34] High on the list for transfer to space are the AWACS and JSTARS surveillance functions.[35]

Conceptually, this approach differs from all others previously mentioned because of the medium in which the radar surveillance platform operates. Table 3 provides examples, in general terms, of the futility of "mirror imaging" tactics in the air and (earth orbit) space mediums.

Table 3. Contrast of Air and Space: Physics of Movement

	in AIR (atmospheric)	*in SPACE (vacuum)*
MOVEMENT		
Speed	**relatively slow, variable**	**relatively fast, continuous**
Forward Linear Acceleration	**increases speed**	**increases speed / altitude**
Maneuverability	**high, can be continuous** structure & stress dependent	**limited, can be periodic** thrust & fuel dependent
Anti-gravitational Force	**lift** (no lift = rapid altitude descent)	**thrust** (no thrust = slow orbital decay)
Standard Operating Area	**Three dimensional** (two dimensional heading + altitude)	**Two dimensional** (orbital plane)
Navigational Factors	**speed, heading, altitude, lat/long etc.**	**right ascension, argument of perigee, semi-major axis, period, etc.**
Terminology Contrast	**Orbit = *stationary* location above earth** (random, circular, cap etc.)	**Orbit = *movement* around the earth** (geosynchronous, highly ellyptical, polar etc.)

For the layman, consider that earth satellites maintain a *constant, two-dimensionally fixed* orbit. The orbit can be changed to a second orbital plane, or third orbital plane, etc. (by drawing upon a finite amount of onboard fuel during each plane change) but this is not the same as operating in three dimensions continuously. While the satellite is on its *constant, fixed* orbital plane, the earth *spins through* the fixed orbital plane, which explains why the satellite can cover a diverse geographical area.

In order for global, continuous radar coverage at low earth orbit (between 60 and 300 miles above the earth's surface)[36], a large constellation of satellites would be required. This "bird cage" constellation would include a number of orbital planes with a number of satellites located on each orbit. If for instance, a satellite were traveling over the Middle East providing coverage, a

second satellite would have to travel toward the Middle East, to assume coverage when the primary satellite continued on out of the coverage area. To give this process perspective, the Space Based Infrared Low (SBIRS Low) constellation, which will detect and track strategic and tactical missile launches, will have approximately 24 satellites to ensure global coverage.[37]

Once on orbit, the satellite constellation would need to expend a small amount of fuel periodically for station-keeping (i.e., staying precisely on the same orbit path). The constellation would gather raw data and transmit the data (again, see Figure 2), but all other functions, including most data processing would be accomplished at a ground station. Incentives for not including significant processing hardware include: (1) the added weight and thus cost for boosting the payload into orbit, and (2) greater need for internal redundancy (i.e., back up processing systems) due to limited maintenance capabilities (i.e., only telemetric guidance from the ground). The total concept would include radar surveillance satellites, communications relay satellites, and ground C2 centers.

A radar satellite *sub-concept* already exists. Large single radar satellites, would be replaced by clusters of 16 smaller, inflatable radar satellites. The cluster would use bistatic technology (each radar can use radar returns from the other 15 satellites for detection) rather than monostatic technology of today's radars (each radar capable of only using its own radar returns).[38]

One strength of the radar sensor satellite: Optimal look down surveillance coverage not limited by mountainous terrain, or curve of the earth—to include no lost coverage for enemy aircraft flying "nap of the earth." With enough satellites (or clusters of satellites) to create an adequate constellation, a second strength would be unprecedented global air surveillance coverage. Third, coverage would be provided instantaneously to theater users without the usual deployment of an air asset (AWACS) into the theater of operations. Fourth, the control function

could be performed by a ground C2 center, such as the Air Operations Center (AOC) in theater, with potential backup by other AOCs either in the same region, other regions, or from the CONUS, via satellite communications.

While the capabilities of space-based radars provides certain strengths, space-based systems perform in highly predictable orbits. A weakness, then, is that many orbit characteristics can be estimated simply by being aware of a satellite launch and the satellite's mission. While few man-made threats to satellites exist today, the technology exists to create anti-satellite weapons to include (1) ground-based lasers and other particle beam weapons, (2) ground launched kinetic-kill weapons, (3) electronic countermeasures, including potential jamming of radio links which transmit satellite data, and (4) boost into low earth orbit and detonation of a nuclear warhead. In the nuclear scenario, the electromagnetic pulse (EMP), unhampered by atmosphere, would damage/destroy satellites over a relatively large area without performing the unthinkable (i.e., using nuclear weapons against an enemy's human element).

Other potential weaknesses, along with already-mentioned strengths are found in Table Four:

Table 4. Contrast of Air and Space: Capability vs. Accessibility/Vulnerability

	in AIR (atmospheric)	*in SPACE (vacuum)*
CAPABILITY		
Surveillance coverage	limited by line-of-sight	line-of-site not a factor
Coverage area per sensor	Tactical or small ops theater continuous	global overflight period only
ACCESSIBILITY		
maintenance	hands-on LIMFAC: in-theater parts replacement	telemetric LIMFAC: no parts replacement
Launch and recovery	routine, short-term activity	limited, long-term activity
Fuel for maneuver	refuelable	non-refuelable
VULNERABILITY		
Location	low predictability based on varying route	high predictability based on stable orbit
Targeting	many threats, but lower PK	few threats, but higher PK
Damaged platform's replacement	usually hours or days	usually months or years
Launch area	Airfield – many available	Space port –few available

Additionally, the space-based radar concept will need to address other AWACS sensor capabilities: Identification Friend or Foe (IFF), and ESM. Both are integral to controlling the air battle space. Last, if ground force detection capabilities (JSTARS) are required from the radar satellite concept, in addition to air vehicle detection capabilities or maritime surface surveillance (AWACS), then all these requirements add up to radar multi-mode capabilities, and ability to tailor mode-usage to the situation at hand.

Concept 3: Airborne Warning and Control Shared Between a Variety of Assets

From the above discussion, one can determine that at least three viable platforms exist: (1) the *traditional AWACS platform* with potential ground surveillance capability, (2) the *AEW UAV*, either employed en masse or as an extension of the traditional platform, and (3) the air surveillance and possibly ground-surveillance *radar-satellite constellation*. Note that the second and third option separate both the human element and the computer processing element from the

data gathering element (See Figure 3, below). Also note, in this concept that the sensor no longer has capability for semi-autonomous or autonomous operations (AWACS has this capability); therefore, possibly the ground station, and particularly, the communications link potentially becomes a decisive point affecting the critical node of theater air surveillance. On the other hand, limitations of AWACS are line-of-sight sensor coverage, (safe) orbit location, and the requirement for in-theater basing. UAVs, because they are much smaller than our manned platforms today, have the limitation of a smaller radar coverage area. Because a "pure sensor" AEW platform would be much more inexpensive than our present AWACS platform, the sensory function could be dispersed among a large number of sensors. The AEW UAV, however, needs in-theater basing and is a 360 degree emitter which draws the enemy's attention.

All three platforms, in essence, have strengths and weaknesses. Each has the potential for providing redundancy and/or synergy if used in tandem at the proper time and place. For instance, a few AEW UAVs could significantly extend the radar range of an AWACS in a moderate air threat environment across the FEBA. An AWACS-like platform could provide redundancy and back-up to a satellite sensor constellation; doing so would substantially lessen the risk of decisive points caused by the *requirement* for communication link(s) between the sensor and the secondary location shown in Figure 3. The AWACS would have, as it does today, semi-autonomous and autonomous mode that does not rely on satellite communications but on radio or radio-relay. Stealth fighters could place a radio in receive-only mode to acquire a data-linked air/ground picture, as a backup to the satellite link. In short, significant weaknesses of each system could be overcome merely by being used in tandem with a second air surveillance platform.

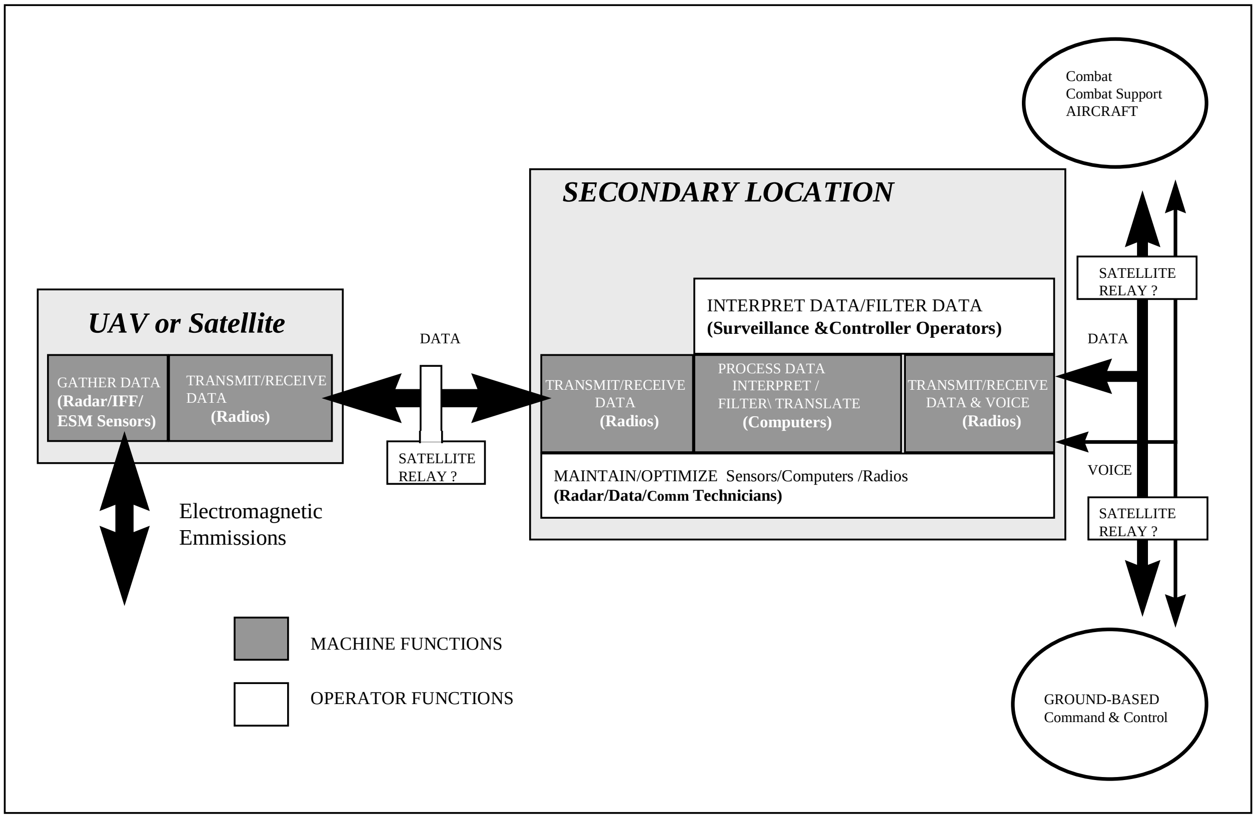

Figure 3. Space or UAV Air Surveillance Radar Concept

Conclusion

Certain directed energy systems such as lasers or highpower microwave (HPM) weapons could be used to disable or negate satellites…The predictability of orbits and the remoteness of space complicate the ability to protect spacecraft from attack.

- Lt Col (Dr.) Mark E. Roberts
Lasers in Space: Technological Options for Enhancing US Military Capabilities

Invincibility lies in the defense; the possibility of victory in the attack.

- Sun Tzu

This study's intent was to examine several warning & control concepts to determine which best fulfills warning and control roles, and to factor in survivability in the high threat environment of tomorrow. Warning and control systems contribute significantly to information superiority. With the overwhelming victory of the Gulf War, the US discovered that decisive force can be inflicted when information superiority exists. USSPACECOM assets provided unprecedented support to the warfighter through space systems. Joint Vision 2010 states that "The unqualified importance of information will not change in 2010. What will differ is the increased access to information…"[39] If, in our thirst for information, we completely migrate the air surveillance sensor function to the "god's eye view" from space, we may indeed create a decisive point from which, should information "decapitation" take place, we would have a hard time recovering.

It is paramount we remember that the AWACS capability is not only a *centralized control* enhancer that provides real-time air surveillance and order of battle information to the commander—it is also a critical tool for successful decentralized execution. If the USAF maximizes the platform's strategic value while placing the control value—that "situation awareness" given to the fighter pilot—at risk, we may have begun a retreat from our own tenants and the history that predated them. The ability to provide information on the strategic, operational, and tactical levels must be protected, but of paramount importance is the operational and tactical levels where the war is prosecuted.

On December 30, 1998, U.S. Representative Christopher Cox, who heads the Select Committee on US National Security and Military/Commercial Concerns with the People's Republic of China, stated: "The PRC's targeting of sensitive US military technology is not limited to missiles and satellites, but covers other military technologies. Sensitive US military technology has been the subject of serious PRC acquisition efforts over the last two decades…"[40] The December 14, 1998 *Air Force Times* reported that China, with the possible help of former Soviet scientists, might be developing an anti-satellite laser weapon that could disable US satellites. Richard D. Fisher, Senior Policy Analyst for The Heritage Foundation, warns that the US should implement plans to more sufficiently protect US satellites in space.[41] He also states the following:

> Lasers are designated a priority technological investment area by the "863" technology development program, China's response to the Reagan Administration Strategic Defense Initiative. Recent PLA writing on future warfare also reflects an appreciation of the potential role of laser weapons… Russia remains a potentially rich source of military laser technology for China. Since the 1960's, several design bureaus have been developing laser weapons… Russia has produced or conducted research on free electron, gas, and CO^2 lasers and ultra-high frequency directed energy weapons.[42]

While all this does not add up an *existing* high threat to our deployed satellite assets, it should cause us to pause and consider the *implications* of migrating *all* of our air surveillance capabilities to space, simply because the technology exists to do so. A mix of different platforms, each with their own strengths and vulnerabilities, defused through the two distinct mediums of air and space, will guarantee the high-value warning and control function survives to face the future air threat that lies ahead.

Notes

[1] Lt Col Bart Dannels, AWACS' Mission Challenges Executive Summary, staff briefing, December 1997, 13.

[2] Ibid., 3.

[3] Ibid., 4.

[4] Ibid., 4.

[5] Ibid., 10.

[6] MCM 3-1, Volume XV. Lt Col Bart Dannels, in AWACS' Mission Challenges Slide Notes,
staff briefing, December 1997, 13.

[7] Air Force Doctrine Document (AFDD) 1, *Air Force Basic Doctrine*, September 1997, 23.

[8] Ibid., 25.

[9] Ibid., 26.

[10] Ibid., 27.

[11] Dannels, AWACS' Mission Challenges Executive Summary, 1.

[12] Ibid., 6.

[13] "U.S. Navy: Vision… Presence… Power," n.p.; on-line, Internet, 30 November 1998, available from http://www.chinfo.navy.mil/navpalib/policy/vision/vis-p08.html.

[14] Ibid.

[15] John Rhea, "Upgraded E-2C With CEC Capable Computer Begins Test Flights," *Military & Aerospace Electronics* 8, issue 5 (May 1997): 1.

[16] "U.S. Navy: Vision… Presence… Power," n.p.

[17] Ibid.

[18] Rhea, "Upgraded E-2C With CEC Capable Computer Begins Test Flights," 2.

[19] Dannels, AWACS' Mission Challenges Executive Summary, 1.

[20] Philip Butterworth-Hayes, "AEW Phased Array Widens Its Reach," *Aerospace America*, March 1995, 43.

[21] Ibid.

[22] Ibid., 44.

[23] Richard D. Fisher, "How America's Friends Are Building China's Military Power," *Heritage Foundation Roe Backgrounder* no. 1146, 5 November 1997, n.p.; on-line, Internet, 10 December 1998, available from http://www.heritage.org/library/categories/natsec/bg1146.html.

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[25]"MFI, 1-42/1-44, MiG-1.42, Mikoyan-Gurevich," The University of Arizona Department of Physics, n.p.; on-line, Internet, 21 February 1999, available from http://www.physics.arizona.edu /~savin/ram/I-42.html.

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[27] Ibid, n.p.

[28] Butterworth-Hayes, "AEW Phased Array Widens Its Reach," 44.

[29] Dannels, AWACS' Mission Challenges Executive Summary, 13.

[30] Paul G. Kaminski, "The FY 1996 DOD RDT&E Program," Research and Development Subcommittee, House Committee on National Security, 28 March 1995, 1-16; on-line, Internet, 27 September 1998, available from http://www.acq.osd.mil/ousda/testimonies/fy96dodresearch. html.

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[32] Steven P. Howard, "Special Operations Forces and Unmanned Aerial Vehicles: Sooner or Later?" (Maxwell AFB, Ala.: School of Advanced Airpower Studies, 1995), 20.

[33] Ibid, 22.

[34] Craig Covault, "USAF Shifts Technology For New Future in Space," *Aviation Week & Space Technology*, 17 August 1999, 44..

[35] Ibid.

[36] Tamar A. Mehuron, ed., "Space Almanac." *Air Force Magazine* 80, no. 8 (August 1997): 40.

[37] Gen. Howell M. Estes, "Sustaining the Strategic Space Advantage," Statement before the Senate Armed Forces Committee, 13 March 1997, in *American Forces Information Service Defense Viewpoint* 12, No. 15, n.p.; on-line, Internet, 10 March 1999, available from http:// www.defenselink.mil/speeches/19970313-etes.html.

[38] Covault, "USAF Shifts Technology For New Future in Space," 44.

[39] Joint Chiefs of Staff, *Joint Vision 2010*, 16.

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Glossary

ABCCC	Airborne Command, Control & Communications (platform)
AEW	Airborne Early Warning
AOC	Air Operations Center
AOR	Area of Operations
ATO	Air Tasking Order
AWACS	Airborne Warning & Control System
C2	Command & Control
C4I	Command, Control, Communications, Computers, and Intelligence
CAS	Close Air Support
ECCM	Electronic Counter Counter Measures
EMP	Electromagnetic Pulse
ESM	Electronic Support Measures
EW	Electronic Warfare
FEBA	Forward Edge of the Battle Area
GPS	Global Positioning System
IFF	Interrogation Friend or Foe
IOC	Initial Operating Capability
LIMFAC	Limiting Factor
JSTARS	Joint Surveillance Target Attack Radar System
JTIDS	Joint Tactical Information Distribution System
MCE	Modular Control Element
MFI	Multi-Role Fighter *(Russian)*
MSSA	Multi-Sensor Surveillance Aircraft
PK	Probability of Kill
PRC	People's Republic of China
QDR	Quadrennial Defense Review
RMA	Revolution in Military Affairs

RSIP	Radar System Improvement Program
SAM	Surface to Air Missile
TACS	Tactical Air Control System
UAV	Unmanned Aerial Vehicle

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